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AUTHOR Gamache, LeAnn M.
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ABSTRACT

To support the construct validity of a locally developed, sixth grade reading achievement test, an investigation of factorial invariance was made across 1556 majority, 327 Black minority, and 136 Asian minority examinees. Although the hypothesis of a unidimensional factor pattern was retained for each group, hypotheses of equal factor weights between the majority group and each minority group were rejected. A standard test score interpretation is thus not possible across these groups. It is suggested that developers and users of achievement tests intended for similar populations should routinely examine factorial invariance across racial groups to support the construct validity of their tests. (Author/BS)

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The Examination of Factorial Invariance in the Construct Validation of a Reading Achievement Test

LeAnn M. Gamache

The University of Iowa

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ABSTRACT

To support the construct validity of a reading achievement test, an investigation of factorial invariace was made across majority, Black minority, and Asian minority examinees. Although the hypothesis of a unidimensional factor pattern was retained for each group, hypotheses of equal factor weights between the majority group and each minority group were rejected. A standard test score interpretation is thus not possible across these groups. It is suggested that developers and users of achievement tests intended for similar populations should routinely examine factorial invariance across racial groups to support the construct validity of their tests.

THE EXAMINATION OF FACTORIAL INVARIANCE IN THE CONSTRUCT VALIDATION OF A READING ACHIEVEMENT TEST

INTRODUCTION

Several issues face test developers and users when assessment instruments are used to collect and summarize information about examinee performance or other characteristics. Perhaps the most critical of these is construct validity, since it determines the very meaning which can be attached to the test score. Construct validity is "demonstrated through careful test development and subsequent relational studies that show that the proposed measure is not contaminated by extraneous variables that would distort the meaning of the test score" (Committee to Develop Joint Technical Standards for Educational and Psychological Testing, p. 2-5, 1983). The construct validation process should involve a system of studies of the success of inclusion of relevant factors and exclusion of irrelevant factors which could affect test meaning and use. Because the universe of factors needing to be examined is delineated by experience with similar measures and groups, findings and implications of a given validation study are of interest beyond the situation of the specific user and test instrument.

Examination of the invariance of factor structure across examinee subgroups is one of several types of studies appropriately included in the construct validation process for academic achievement tests. Unless the theory underlying a specific curricular area indicates the relationships among specific tasks should differentiate between certain groups, no differences should be found. In reading, for example, there is no theoretical reason to expect that the definition of "reading", or the interrelationships between its components, should differ between racial groups. Should a study of the factorial invariance of a reading achievement test reveal a difference, the test score can not be interpreted as measuring the same construct for all groups. The measure of reading achievement would thus be biased by some construct confounding its measurement.

Several studies of factorial invariance of ability and intelligence tests have been reported, but few are offered as part of a routine system for investigation of construct validity. McGaw & Jorsekog (1971), examining invariance of scores on twelve aptitude and achievement tests across groups defined by intelligence and socio-economic status, did not reject the hypothesis of equal factor loadings for the groups for a four factor model. Other studies have examined factorial invariance across racial or ethnic groups. Gutkin & Reynolds (1980) examined the WISC-R and reported

congruence of a two factor model for Anglo and Chicano children. Jensen & Inouye (1980), examining a battery of intelligence, achievement, and short term memory tests, indicate that two factors (memory and general intelligence) structure achievement. Groups of Asian-American, White, and Black children were reported to differ with regard to this structure at each grade level from grade two to grade six. Hennessy & Merrifield (1976) undertook the study of factorial invariance of the CEEB Comparitive Guidance and Placement Battery over Black, Spanish, Jewish, and Caucasian-Gentile groups specifically to investigate the validity of the test battery. They report no meaningful differences were found.

The purpose of this study is to examine the factorial invariance of a locally developed test of reading achievement. Results of such a study may have implications for study of test and item bias, test revision, and test score interpretation for this specific test as well as implying need for similar studies in the construct validation of other reading achievement tests.

METHODOLOGY

INSTRUMENTATION: The test analyzed is one of a series of grade level tests in Reading, Language Arts, and Math locally developed to assess basic, core behavioral objectives for instruction at the respective grade levels within a large urban school district. Each set of objectives and its

content specifications was developed from concensus of curricular experts, then translated into multiple choice items, reviewed, revised, field tested, and evaluated for item quality before inclusion in the final test form. The test consists of 85 multiple choice items arranged into fourteen subtests by learning objective. A description of the subtest topics, number of items, and abbreviations used in this study are given in Table 1. The three cloze subtests, although of multiple choice format, differ from the others in that (1) the alternatives are not contiguous to the item stems and (2) the items within each cloze passage are quite dependent. In these subtests, attention span and/or perseverence might affect examinee performance. It was therefore postulated that these differences defined two underlying factors structuring examinee performance.

PROCEDURE: Data from the fall 1982 assessment of sixth grade students in a large urban school district were used. In the first phase of the study, the responses of the 1556 majority group students were analyzed to determine the underlying factor structure of the test using maximum likelihood estimation procedures in LISREL V (Joreskog & Sorbom, 1981). In the notation of LISREL, estimates of parameters are determined such that $\underset{\sim}{\Sigma}xx = \underset{\sim}{\Lambda}x\underset{\sim}{\Phi}\underset{\sim}{\Lambda}x + \underset{\sim}{\Theta}d$, where $\underset{\sim}{\Sigma}xx$ is the covariance matrix, $\underset{\sim}{\Lambda}x$ is a matrix of factor weights, $\underset{\sim}{\Phi}$ is the matrix of covariance between factors, and $\underset{\sim}{\Theta}d$ is a diagonal matrix of uniquenesses.

In the second stage of the study, hypotheses were tested regarding the invariance of the majority group factor structure for 327 Black sixth grade students and 136 Asian students: (1) assuming the factor analysis model of the form $\underset{\sim}{x}=\underset{\sim}{\Lambda}_x \underset{\sim}{\xi} + \underset{\sim}{\delta}$ held in all groups, the hypothesis of identical factor patterns was to be tested for the majority-to-Black and the majority-to-Asian group pairings; (2) assuming identical factor patterns, the hypothesis of equal factor loadings, Ho: $\underset{\sim}{\Lambda}_x$(majority)=$\underset{\sim}{\Lambda}_x$(minority), was to be tested for each group respectively; (3) assuming equal factor loadings, the hypothesis of equal uniquenesses or errors of measurement, Ho: $\underset{\sim}{\Theta}_\delta$(majority) = $\underset{\sim}{\Theta}_\delta$(minority), was to be tested for each minority group; and (4) assuming equal uniquenesses or errors of measurement, the hypothesis of equally strong relationships among the factors, Ho: $\underset{\sim}{\Phi}$(majority) = $\underset{\sim}{\Phi}$(minority) was to be tested for each minority group.

RESULTS

Descriptive statistics regarding performance of the groups is given by subtest in Table 2. Black group means are less than those for the majority group for all subtests and are generally also less than means for the Asian group. The covariance matrices used as input to the analysis are given in Tables 3a through 3c.

The first phase of the investigation was to determine the factor structure of majority group performance on the test. Results of the analysis postulating a two factor structure are given in Table 4 and indicate that communalities are rather large and similar across subtests. Also the θd coefficents are generally close to the magnitude of the factor loadings. The coefficient of determination, ranging from 0 to 1, was .897. The goodness of fit index, also ranging from 0 to 1, was found to be .904. The root mean squared residual was .131. The correlation of the factors was .904, indicating a very high relationship between the two postulated factors.

The possibility of identifying a more parsimonious solution was examined. Results of the analysis postulating a single factor are given in Table 5. Specification of a single factor generally reduced the standard errors of estimate of the factor weights and uniqueness weights. The indices of model fit were relatively unaffected. The viability of a single factor model was further supported using the factor analysis program in SPSS (Nie, Hull, Jenkins, Steinbrenner, & Bent, 1975) which determined 52.8% of the variance in examinee performance was accounted for by the first factor, having an eigenvalue of 7.388, and a first to second factor eigenvalue ratio of 7.388/0.987. Following Varimax rotation, 79.3% of the variance was accounted for by the first

factor, which had an eigenvalue of 7.000 and a first to second factor eigenvalue ratio of 7.000/.601. For purposes of studying the factorial invariance across the groups, a single factor model was therefore used. Figure 1 diagrams the model.

In the second stage of the study, several hypotheses were tested regarding equivalence of various aspects of factor structure between the majority and minority groups. Results of testing these hypotheses are given in Table 6. The first hypothesis tested whether the factor pattern was the same for the majority and minority groups by fitting the unidimensional pattern for the majority group to each of the minority groups in turn. The unidimensional pattern fit the performance of the minority groups slightly less well than the majority group. For the Black group, the goodness of fit index was .860 with a root mean squared residual value of .186. The coefficient of determination was .831. For the Asian group, the values of these indices of fit were .857, .130, and .865 respectively. The Asian group fit the unidimensional pattern somewhat better than the Black group.

Although the chi-square values for both comparisons were significant, the other indices indicate the difference in fit was slight. Eigenvalues and the ratio of first to second factor eigenvalues were examined to determine whether the significance of the chi-square values was an artifact of

the large sample sizes. For the Black group, 46.6% of the variance was accounted for by the first factor, which had an eigenvalue of 6.522 and a first to second factor eigenvalue ratio of 6.522/1.189. Following Varimax rotation, these values were 71.7%, 6.15 and 6.15/.822 respectively. For the Asian group, 58.4% of the variance was accounted for by the first factor, having an eigenvalue of 8.179 and a first to second eigenvalue ratio of 8.179/.85. Following Varimax rotation these values were 76.8%, 7.929 and 7.929/.596 respectively. The significance of the chi-square values, therefore, was deemed to be an artifact of the very large samples, and the hypothesis of identical factor patterns was retained for both minority groups. Results of the analyses for each of the minority groups are given in Tables 7 and 8. Figure 2 provides a comparative summary of the parameter values for the majority and minority groups.

The second hypothesis concerned the equality of the factor weight matrices between each minority group and the majority group. This hypothesis was rejected for both minority groups. For the Black group, a further decline in fit was evidenced by a coefficient of determination of .794, a goodness of fit index of .763, and a root mean squared residual value of .333, in conjunction with a significant chi-square value. Fit declined for the Asian group as well, as indicated by a coefficient of determination of .808, a

goodness of fit index of .656, and root mean squared residual value of .452, in addition to a significant chi-square value.

Rejection of the hypotheses of the equality of factor weight matrices precluded the possibility of testing hypotheses of the equality of uniquenesses. Testing the equality of the covariance between factors was unnecessary since analyses in the first phase of the study indicated a unidimensional structure for the majority group.

DISCUSSION AND CONCLUSION

These findings have implications for interpretation of these test scores, test revision, and the need for further study of examinee performance based on this test instrument. The weaker factor weights for the minority groups indicate that reading achievement has less effect on observed test performance for these groups than for the majority group. The inference of achievement in reading from scores on this test is thus made with less accuracy for minority examinees. This raises a series of questions regarding possibilities that

1) an overall bias in the testing may exist;

2) the cognitive structure of reading may differ across these racial groups;

3) the instructional system may have created an artificial difference in the reading construct by teaching reading, for example, in segmented skill blocks for minority students and a synthesizing approach for the majority group; or

4) variables inherent to the format and method of testing may differentially impact the groups.

Such possibilities require investigation before one can decide to make differential score interpretations, revise the test or testing process, or revise the instructional process. Anomalies in the general pattern of differences, beyond that expected by sampling error, may indicate the need for study of item (in this case subtest) bias.

Follow-up of these research questions would be appropriate in the process of establishing the construct validity of this test. The need for study of group differences is not limited, however, to this specific test or testing situation. The rejection of the overall hypothesis of factorial invariance gives notice to developers and users of similar achievement tests that study of factorial invariance should routinely be considered in the construct validation of their assessment instruments.

Table 1

Description of the Fourteen Subtests

Subtest Abbrev.	No. Items	Description
CLOZEA	10	Cloze passage, readability 4.5
CLOZEB	10	Cloze passage, readability 6.8
		From context:
CONTXTMN	5	Select meaning of unfamiliar words
MULTMN	5	Choose meaning of word having multiple meanings
SYNANT	5	Match synonyms and antonyms
ROOTWD	5	Identify root word
		From reading given passage:
RECALL	5	Recall information
PREDICT	5	Predict outcome
INFRNCE	5	Make inferences
SUMRZE	5	Summarize passage
FIVEWS	5	Answer who, what, where, why, and how
BKPRTS	5	Identify parts of book to find information
REFRNCE	5	Identify appropriate reference sources
CLOZEC	10	Cloze passage, readability 7.9

Table 2

Means and Standard Deviations for Subtest Performance by Group

Subtest	Majority		Black		Asian	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
CLOZEA	8.73	1.80	8.1	2.23	7.83	2.32
CLOZEB	7.18	2.47	6.28	2.63	6.56	2.63
CONTXTMN	4.03	1.21	3.58	1.35	3.49	1.42
MULTMN	3.6	1.52	2.79	1.61	2.98	1.85
SYNANT	4.47	1.39	2.76	1.54	3.15	1.43
ROOTWD	3.13	1.34	2.77	1.31	2.9	1.38
RECALL	2.92	1.54	2.31	1.48	2.99	1.64
PREDICT	2.83	1.62	2.11	1.42	2.63	1.56
INFRNCE	3.62	1.51	2.91	1.57	3.38	1.55
SUMRZE	3.26	1.53	2.69	1.54	3.35	1.52
FIVEWS	3.10	1.70	2.39	1.55	3.18	1.64
BKPRTS	2.88	1.53	2.18	1.42	2.71	1.54
REFRNCE	3.37	1.53	2.72	1.51	3.4	1.56
CLOZEC	5.61	3.15	4.21	2.84	5.28	2.92

Table 3a

Observed Covariance Matrix - Majority Group

	CLOZEA	CLOZER	CONTXTMN	MULTMN	SYNANT	ROOTWD	RECALL	PREDICT	INFERNCE	SUMRZE
CLOZEA	3.250									
CLOZER	2.643	6.122								
CONTXTMN	1.012	1.652	1.459							
MULTMN	1.311	2.359	1.039	2.312						
SYNANT	1.011	1.801	0.756	1.146	1.923					
ROOTWD	0.872	1.481	0.623	0.992	0.794	1.806				
RECALL	1.128	2.046	0.831	1.273	0.975	0.865	2.368			
PREDICT	1.068	2.042	0.766	1.259	0.990	0.909	1.365	2.619		
INFERNCE	1.192	2.188	0.899	1.374	1.022	0.910	1.304	1.364	2.292	
SUMRZE	1.194	2.155	0.825	1.317	1.003	0.817	1.282	1.329	1.226	2.339
FIVEWS	1.178	2.315	0.923	1.441	1.040	0.922	1.468	1.528	1.526	1.633
ARPRIS	0.933	1.848	0.747	1.095	0.876	0.835	1.074	1.142	1.181	1.314
REFRNCE	0.938	1.837	0.708	1.021	0.747	0.787	0.881	0.938	1.118	1.214
CLOZEC	2.174	4.380	1.662	2.717	1.966	1.765	2.517	2.748	2.749	2.912

COVARIANCE MATRIX TO BE ANALYZED

	FIVEWS	ARPRIS	REFRNCE	CLOZEC
FIVEWS	2.899			
ARPRIS	1.428	2.353		
REFRNCE	1.408	1.291	2.316	
CLOZEC	3.458	2.816	2.775	9.937

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Table 3b

Observed Covariance Matrix - Black Minority Group

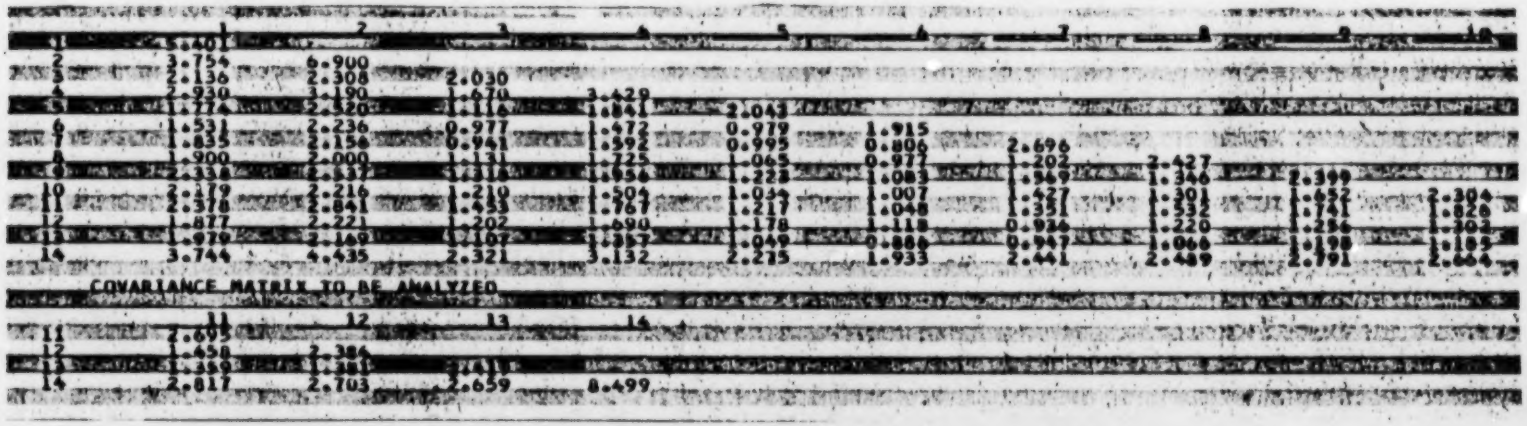
	1	2	3	4	5	6	7	8	9	10
1	7.990									
2	3.697	6.938								
3	1.569	1.958	1.834							
4	1.748	2.452	1.115	2.604						
5	1.502	2.257	0.991	1.321	2.366					
6	1.212	1.655	0.791	1.063	0.937	1.709				
7	1.212	1.632	0.749	1.081	0.846	0.809	2.194			
8	0.787	1.605	0.480	0.769	0.735	0.626	0.724	2.006		
9	1.696	2.054	1.000	1.148	1.146	0.825	1.020	0.912	2.473	
10	1.448	1.889	0.844	1.272	1.056	0.925	1.066	0.964	1.301	2.370
11	1.299	1.697	0.667	1.167	0.880	0.844	1.008	0.846	1.140	1.358
12	0.864	1.471	0.549	0.931	0.687	0.719	0.751	0.627	0.923	0.990
13	1.034	1.395	0.283	0.713	0.647	0.593	0.540	0.485	0.820	0.964
14	2.476	3.711	1.389	2.134	1.664	1.582	1.705	1.869	2.293	2.432

COVARIANCE MATRIX REANALYZED

	11	12	13	14
11	2.399			
12	0.984	2.620		
13	1.068	0.855	2.289	
14	2.539	2.066	2.142	8.069

Table 3c

Observed Covariance Matrix - Asian Minority Group



	1	2	3	4	5	6	7	8	9	10
1	5.401									
2	3.754	6.900								
3	2.136	2.308	2.030							
4	2.930	3.190	1.670	3.429						
5	1.774	2.320	1.116	1.841	2.043					
6	1.531	2.236	0.977	1.472	0.979	1.915				
7	1.835	2.156	0.941	1.592	0.995	0.806	2.696			
8	1.900	2.000	1.131	1.725	1.065	0.977	1.202	2.427		
9	2.338	2.837	1.318	1.954	1.228	1.083	1.349	1.346	2.399	
10	2.179	2.216	1.210	1.504	1.044	1.007	1.427	1.301	1.652	2.304
11	2.378	2.841	1.453	1.767	1.217	1.048	1.351	1.532	1.741	1.826
12	1.877	2.221	1.202	1.690	1.178	1.118	0.934	1.220	1.296	1.302
13	1.979	2.169	1.167	1.357	1.049	0.886	0.947	1.046	1.198	1.189
14	3.744	4.435	2.321	3.132	2.215	1.933	2.441	2.489	2.791	2.664

COVARIANCE MATRIX TO BE ANALYZED

	11	12	13	14
11	2.605			
12	1.458	2.384		
13	1.359	1.381	1.418	
14	2.817	2.703	2.659	8.499

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Table 4

The Two-Factor Model Estimates and Fit Indices

for the Majority Group

Subtest	Factor Weights Factor I (SE)	Factor II (SE)	Uniquenesses (SE)	R SQRD
CLOZEA	0.000(.000)	1.000(.000)	2.121(.080)	.347
CLOZEB	0.000(.000)	1.797(.076)	2.477(.180)	.595
CONTXTMN	1.000(.000)	0.000(.000)	0.862(.032)	.409
MULTMN	1.499(.058)	0.000(.000)	0.970(.039)	.581
SYNANT	1.148(.051)	0.000(.000)	1.136(.043)	.409
ROOTWD	1.014(.049)	0.000(.000)	1.192(.044)	.340
RECALL	1.414(.058)	0.000(.000)	1.174(.045)	.504
PREDICT	1.447(.061)	0.000(.000)	1.369(.052)	.477
INFRNCE	1.502(.058)	0.000(.000)	0.945(.038)	.588
SUMRZE	1.519(.059)	0.000(.000)	0.962(.038)	.589
FIVEWS	1.693(.065)	0.000(.000)	1.188(.047)	.590
BKPRTS	1.339(.057)	0.000(.000)	1.283(.049)	.455
REFRNCE	1.250(.056)	0.000(.000)	1.397(.053)	.400
CLOZEC	0.000(.000)	2.284(.097)	4.052(.176)	.592

Coefficient of determination	0.897
Goodness of fit index	0.904
Root Mean Squared Residual	0.131

Table 5

The One-Factor Model Estimates and Fit Indices

for the Majority Group

Subtest	Factor Weights (SE)	Uniquenesses (SE)	R SQRD
CLOZEA	1.000(.000)	2.134(.079)	.343
CLOZEB	1.799(.077)	2.512(.100)	.590
CONTXTMN	0.731(.035)	0.862(.032)	.409
MULTMN	1.097(.047)	0.970(.038)	.580
SYNANT	0.840(.040)	1.137(.043)	.409
ROOTWD	0.741(.038)	1.193(.044)	.339
RECALL	1.034(.046)	1.176(.045)	.503
PREDICT	1.058(.048)	1.370(.052)	.477
INFRNCE	1.098(.047)	0.946(.038)	.587
SUMRZE	1.111(.047)	0.962(.038)	.589
FIVEWS	1.238(.053)	1.189(.047)	.590
BKPRTS	0.979(.045)	1.283(.049)	.455
REFRNCE	0.915(.044)	1.397(.053)	.400
CLOZEC	2.293(.097)	4.073(.162)	.590

Coefficient of determination	0.894
Goodness of fit index	0.904
Root Mean Squared Residual	0.131

Table 6

Results of Examining Factorial Invariance of

Majority to Minority Groups

	Ho: Identical Factor Pattern	Ho: Equal Factor Weights
Minority: Black		
Chi-Square	998.59*	1060.08*
d.f.	154	167
Coeff of Determ.	.831	.794
Goodness of Fit	.860	.763
Root Mn. Sq. Res.	.186	.333
Minority: Asian		
Chi-Square	900.20*	945.20*
d.f.	154	167
Coeff of Determ.	.865	.808
Goodness of Fit	.857	.656
Root Mn. Sq. Res.	.130	.452

*Values are statistically significant

Table 7

The One-Factor Model Estimates and Fit Indices

for the Black Minority Group

Subtest	Factor Weights (SE)	Uniquenesses (SE)	R SQRD
CLOZEA	1.000(.000)	2.892(.243)	.443
CLOZEB	1.350(.117)	3.116(.275)	.551
CONTXTMN	0.588(.058)	1.110(.092)	.395
MULTMN	0.804(.071)	1.249(.109)	.521
SYNANT	0.694(.067)	1.356(.114)	.427
ROOTWD	0.583(.057)	0.997(.084)	.417
RECALL	0.617(.063)	1.398(.115)	.363
PREDICT	0.518(.060)	1.445(.117)	.280
INFRNCE	0.762(.069)	1.254(.108)	.493
SUMRZE	0.774(.068)	1.113(.097)	.530
FIVEWS	0.721(.067)	1.310(.111)	.454
BKPRTS	0.573(.061)	1.330(.109)	.341
REFRNCE	0.537(.064)	1.685(.136)	.264
CLOZEC	1.393(.125)	3.999(.346)	.504

Coefficient of determination	0.831
Goodness of fit index	0.860
Root Mean Squared Residual	0.186

Table 8

The One-Factor Model Estimates and Fit Indices

for the Asian Minority Group

Subtest	Factor Weights (SE)	Uniquenesses (SE)	R SQRD
CLOZEA	1.000(.000)	2.092(.279)	.613
CLOZEB	1.148(.112)	2.540(.341)	.632
CONTXTMN	0.592(.062)	0.870(.114)	.572
MULTMN	0.826(.079)	1.171(.159)	.658
SYNANT	0.567(.063)	0.979(.127)	.521
ROOTWD	0.496(.062)	1.102(.140)	.425
RECALL	0.573(.074)	1.608(.203)	.404
PREDICT	0.595(.069)	1.257(.161)	.482
INFRNCE	0.698(.066)	0.788(.108)	.672
SUMRZE	0.647(.065)	0.919(.122)	.601
FIVEWS	0.726(.070)	0.949(.128)	.648
BKPRTS	0.607(.068)	1.163(.150)	.512
REFRNCE	0.564(.069)	1.365(.173)	.436
CLOZEC	1.211(.126)	3.648(.478)	.571

Coefficient of determination	0.865
Goodness of fit index	0.857
Root Mean Squared Residual	0.130

Figure 1

The Factor Model

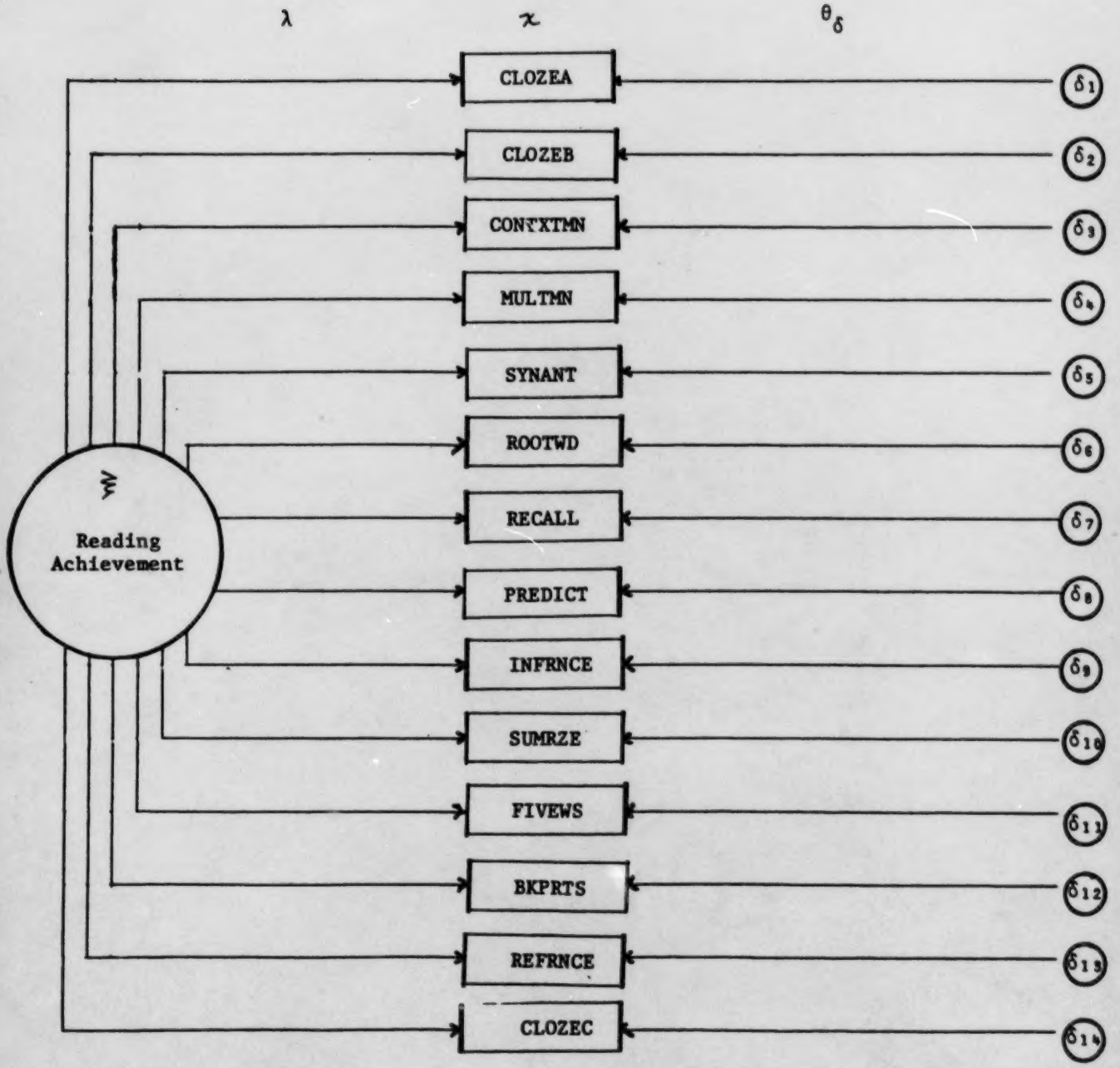
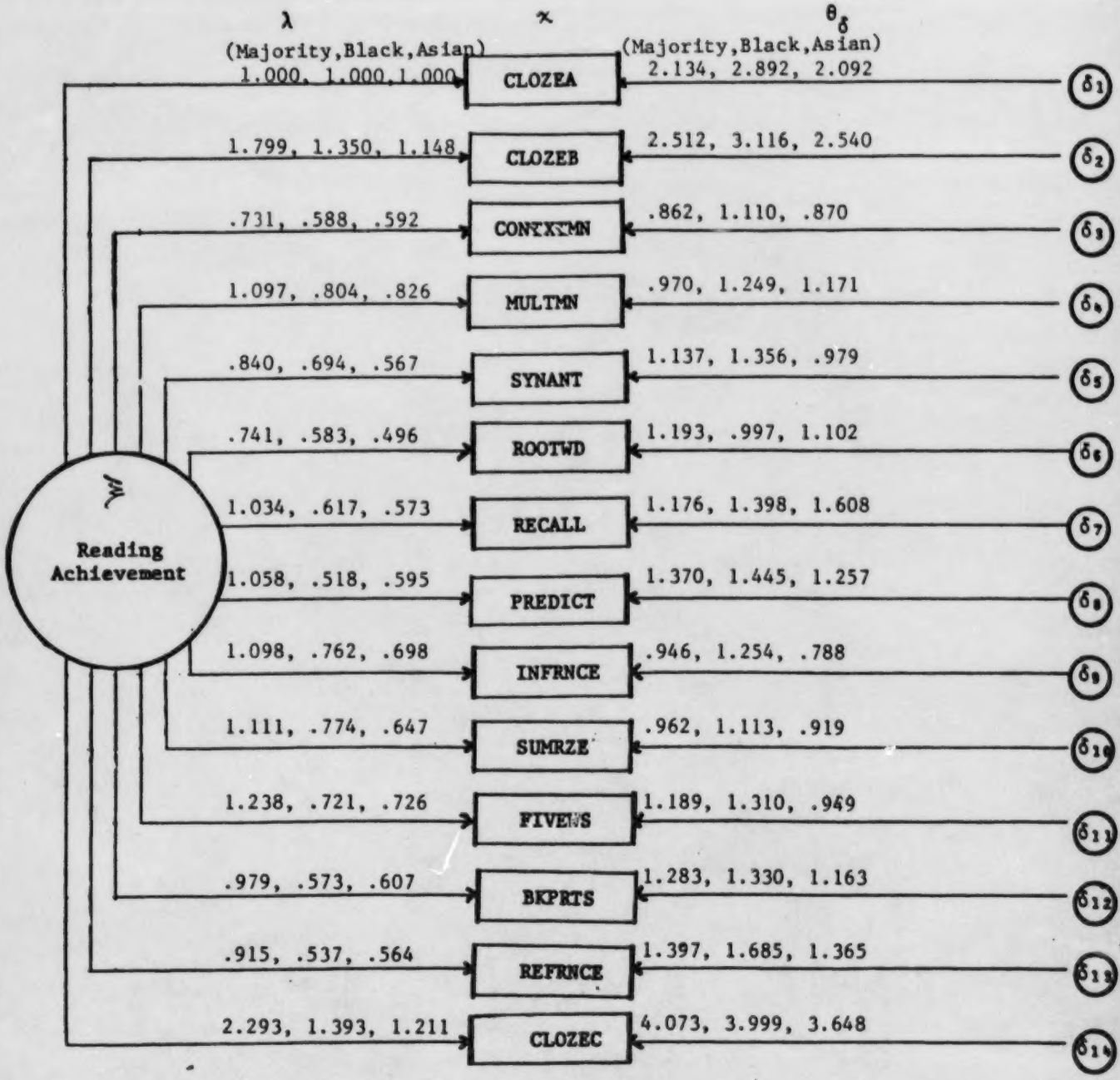


Figure 2

Comparative Summary of Group Factor Structure Parameters



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